SOME CONSIDERATIONS CONCERNING ANTISEPTIC SURGERY.

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Reprinted from the Maryland Medical Journal of November 14, 1891.

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The greatest achievement of modern surgery is not so much the triumph of abdominal or of cerebral surgery, or of any particular class of operations, as it is the method which has brought into the surgeon's domain every organ of the human body. The victories of this method are manifested not less in the aseptic healing of the wound resulting from the removal of a simple wen, than in the recovery without suppuration and fever after the extirpation of a cerebral tumor, or of a large abdominal tumor.

Modern surgery begins with the introduction of antiseptic methods of wound treatment, and it is the imperishable merit of Lister to have ushered in this era by his recognition of the great truth that the infection of wounds depends upon the presence of bacteria and by his adoption of measures of treatment based upon this truth. Upon the establishment of these fundamental principles his fame will rest, even if every detail in his original method of treatment be replaced by means found better suited to the purpose.

No apology is needed if a pathologist ventures to speak to you about a subject with such practical bearings as surgical antisepsis, when it is recalled that antiseptic and aseptic methods of wound treatment rest upon bacteriological work no less than upon clinical experience. In the development of these methods the surgeon and the bacteriologist have worked hand in hand. The harmony and

*An address before the Clinical Society of Maryland, on October 16th, 1891. The address was delivered extemporaneously and this paper is from the stenographer's report, revised by the author.

co-operation between the worker in the laboratory and the practical physician and surgeon have never been so great as at the present time. On the one hand, the experimenter applies himself to problems of immediate interest to the practitioner and seeks the aid of clinical observation as never before, and the practitioner is eager to learn and to apply the established results of experiment. That this combined work is calculated to advance scientific and practical medicine in the surest way cannot be doubted.

Lister's original antiseptic methods, which were introduced about the middle of the sixth decade of this century, were founded mainly upon the views which prevailed at that time as to the relation of bacteria to the processes of putrefaction and fermentation. One chief source of the bacteria which infect wounds was regarded as the air; and by the use of carbolic acid spray he hoped to disinfect the air over the field of operation. Lister also employed carbolic acid as the agent for disinfecting the wound, hands, instruments and all that might come in contact with the wound. The dressings applied to the wound were permeated with the disinfectant and were expensive and somewhat complicated. The method necessitated extensive use of drainage tubes and frequent change of dressings.

The results of this method marked a great advance in surgery, the contrast between the new and the old method being more evident in Germany than in Great Britain, because in the former the hospitals were, in general, older, less cleanly and in a less sanitary condition. Good as were the results of the new method, they were still so far from perfect that efforts continued to be made to improve the method.

It is evidence of the value and fructifying influence of the new ideas introduced by Lister that they have proven capable of wide development; that they have stimulated workers in science and in practical medicine to efforts which have extended our knowledge far beyond the mark of a quarter of a century ago; and that they have occasioned unprecedented activity and progress in surgery during this period. Permit me to direct your attention to some of these advances in the general principles of antiseptic surgery, looking at the subject rather from the point of view of the bacteriologist than from that of the practical surgeon. In the limits of a paper of this kind it is possible to select for consideration only a few points, leaving many of great importance untouched.

The most fundamental advance relates to the extension of our knowledge concerning the nature and habits of the micro-organisms which cause traumatic infections. As has already been said, Lister's early work was based upon analogies drawn from the relation of bacteria to the processes of fermentation and putrefaction. Nothing or almost nothing was known as to the bacteria actually concerned in suppuration and other wound infections. The observations of Klebs, Recklinghausen and others at this period concerning the presence of micrococci in pyæmia and other suppurative conditions gave little information as to the character and behavior of these organisms.

The new era in bacteriology was introduced by the publication of Robert Koch's *Untersuchungen über die Aetiologie der Wundinfectionskrankheiten*, in 1878. The kind of evidence necessary to prove the causation of a disease by a specific micro-organism was here clearly set forth and was brilliantly illustrated by his study of a number of new infectious diseases, chiefly experimental septicæmias, produced in mice and rabbits by the inoculation of foul substances. Three years later, Koch gave to the world the details of his method of cultivating bacteria upon solid transparent media, without which most of the great discoveries in bacteriology during the last decade could not have been made.

Although Koch's epoch-making publication was entitled Investigations Concerning the Etiology of Traumatic Infections, this did not relate to the bacteria which cause wound infections in human beings; and it was hardly less misleading when inferences were drawn as to the nature and mode of causation of suppurative and other traumatic infections of human beings from supposed analogies with Koch's experimental septicæmias, than from those with fermentation and putrefaction.

The first thorough study by modern bacteriological methods of the bacteria causing suppuration in human beings was made by Ogston, Rosenbach and Passet, between the years 1880 and 1885. To this period belongs also the study and first cultivation of the erysipelas coccus by Fehleisen. Ogston confined his attention to the microscopical observation, by the improved optical aids, of the staphylococci and streptococci of suppuration. The other investigators isolated in pure culture and studied the different species of bacteria found in abscesses. These fundamental researches made us familiar with the ordinary pyogenic staphylococci and streptococci. Now, for the first time, the causation of the most common, and, therefore, the most important, of all traumatic infections, namely, the suppurative, could be satisfactorily studied. The commonest enemies of the surgeon were known, their distribution in nature, the ways in which they may gain entrance to wounds, their habits and behavior both inside and outside of the body, were open to direct observation and experiment. It could not be doubted that this increased knowledge would lead to more efficient means of combatting the enemy, and this has proven true.

Although we have learned that many other species of micro-organisms than those originally described by Ogston, Rosenbach and Passet may be concerned in traumatic infections of human beings, nevertheless the pyogenic cocci are by far the most common and important, and these are the ones which have been most thoroughly studied. It soon became evident that the study of infection with the pyogenic cocci presents many peculiar and complicated problems; and we owe especially to Grawitz and his pupils the demonstration that under ordinary conditions, the healthy tissues in many situations are capable of disposing of a large number of these cocci without manifest injury, and also the recognition of several abnormal conditions which deprive the tissues of this power.

It is becoming every day clearer that the most valuable friend which the surgeon has in his efforts to secure aseptic healing of his wounds is the capacity of the fluids and cells of the animal body to overcome invading micro-organisms. The indication is no less urgent than ever before to keep bacteria out of wounds in every way possible, but it seems plain that hitherto the efforts of the antiseptic surgeon have been directed too exclusively toward this indication and toward the attempted destruction of bacteria which may have accidentally entered the wound, and not enough toward preserving, as far as possible, the germicidal power of the tissues and fluids.

Among the influences which have been found favorable to the growth in wounds of bacteria, which otherwise might be disposed of by the tissues and animal fluids without harm, are the presence of foreign bodies, such as drainage tubes and coarse ligatures, the necrosis and degeneration of tissue caused by the contact of strong chemical disinfectants with the wounded tissues, the strangulation of masses of tissue with ligatures, the strangulation, tension and interference with the circulation often caused by deep coaptation sutures, and interference with the circulation and vitality of tissues which may result from too forcible pressure. If it were within the power of the surgeon to keep bacteria entirely

out of wounds, or to destroy them without damage to the tissues after they enter, the conditions just mentioned could not by themselves alone cause infection, but this power he does not at present possess, as is demonstrated by the bacteriological examination of wounds treated aseptically or antiseptically. Hence it behooves him to learn all that he can concerning those conditions which favor and those which are hostile to the development of bacteria in wounds, and to endeavor to retain and produce the hostile and to remove the favorable conditions for the growth of bacteria.

That conditions predisposing to suppurative and septic complications of wounds are to be sought not only in local conditions about the wound, but also in the general state of the patient, is known to every surgeon of experience, and this latter side of the subject has been recently presented in an interesting and suggestive manner by Dr. Roswell Park, in his paper before the Congress of American Physicians and Surgeons.

It has been a stumbling block in the way of the acceptance of the general principles of antiseptic surgery by some, that surgeons who claim to disregard these principles have good results even in operations which were considered unwarrantable before the introduction of antiseptic methods. The foremost champion of these dissenters is, perhaps, Lawson Tait, so widely known as a successful laparotomist. But there is no difficulty in explaining these results, which in reality furnish no sound argument against the employment of proper antiseptic measures in the treatment of wounds. Mr. Tait and his followers make extensive, although not sufficient, use of the most efficient of all antiseptic agents, namely, heat. By attention to cleanliness they greatly diminish the chances of infection of wounds by bacteria. They are often particularly rapid and skillful operators. Above all they respect the vitality of the tissues, especially by withholding the application to them of chemical disinfectants. They do not disregard the principles of antiseptic surgery to the extent that they may suppose they do, but they would be wiser if they paid still more attention to these principles. Because the use of unsterilized ligatures or the washing of the peritoneal cavity with unsterilized water is not attended by bad results in many cases, is no proof that it is not safer to sterilize ligatures and all that comes into contact with a wound.

Moreover, there are special reasons, now well known, why the results of operations in the peritoneal cavity cannot be regarded as the best test of antiseptic methods. The healthy peritoneum is tolerant to an extraordinary degree of the presence of pyogenic bacteria, but when these conditions of tolerance are overstepped then the dangers from infection surpass those from infections of wounds of external parts. These exceptional dangers are what render the employment of proper antiseptic measures especially imperative in laparotomies.

The tendency at the present time to abandon the application of strong disinfectant solutions to fresh wounds and to pay more attention to the gentle handling of wounded tissues has been interpreted by some as a reaction against antiseptic surgery and a return to ideas which obtained in pre-antiseptic days. It is true that the capacity of the living tissues to resist putrefaction and the influence upon the process of healing of the character and condition of wounds are very old conceptions in surgery. The old books on surgery have much to say on these points, and entered into extreme refinements in the classification and description of wounds, with especial reference to their behavior in the process of repair. They contained much sound doctrine in these matters, which can still be perused with profit. But the results of the old and those of the new surgery are

alone sufficient to prove the wide difference between them. Under the old regime the healing of wounds without suppuration was so exceptional that the occurrence could even be disputed by prominent surgeons, whereas now the surgeon with good technique may look with reasonable certainty to this result, once so exceptional. The foundations of antiseptic surgery are strengthened, not shaken, by improvements in details and by the recognition of new principles. Now that we recognize the dangers of applying strong antiseptic substances to wounds and the difficulties of disinfecting wounds in this way, the arguments are stronger than ever before for operating with as nearly sterile surroundings as possible and for keeping the wound from contact with unsterilized objects.

Permit me to say in this connection that I fail to see the advantage of using the term aseptic surgery in the sense in which it is generally employed at the present time as something distinct from antiseptic surgery. One hears on all sides such expressions as that aseptic surgery is displacing or is destined to displace antiseptic surgery. What is understood by aseptic surgery undoubtedly marks an important advance in surgical antisepsis, but it is none the less antiseptic surgery. It would seem as if some supposed that antiseptic surgery means nothing more than the use of chemical disinfectants in the management of wounds, or that antiseptic technique is incapable of improvement. An antiseptic agent is anything which has the power of arresting the development of septic bacteria. With his views as to the influence of blood in a wound in favoring infection, von Bergmann has said that a ligature is one of our most important antiseptic agents. The substitution of heat for chemical substances in the disinfection of instruments, ligatures, dressings, etc., is an important advance but it is only the substitution of a more powerful for a weaker antiseptic agent. The object of antiseptic surgery is to secure an aseptic condition of a wound, and here it may be well to remark that this rarely is equivalent to the condition generally understood in a bacteriological laboratory as aseptic, namely, freedom from bacteria.

The abandonment of disinfectant applications to a wound is for the purpose of securing the action of more efficient antiseptic agencies under the circumstances, namely, the fluids and cells of the surrounding tissues, and this abandonment renders all the more urgent the use of antiseptic agents outside of the wound. It is doubtless one of most useless occupations to contend against current usage in medical nomenclature, but it seems to me unfortunate that the term aseptic surgery should be introduced as if it signified something different from antiseptic surgery and not simply an improvement in the methods of antiseptic surgery.

It is interesting from a bacteriological point of view to note the improvement in the dressing and management of wounds since the pioneer work of Lister. The early efforts in this direction, especially in Germany, were to render the dressings less expensive and less cumbersome, items of no small consideration in a hospital with limited resources. Important advances in principle, however, resulted from the efforts to do away with the frequent changing of surgical dressings, which was necessitated by Lister's early method. The employment of absorbent material for the dressings without the outside impermeable covering adopted by Lister, permits rapid drying of the secretions and, therefore, rests upon the sound basis that bacteria find in moist media opportunities for their growth not furnished by dry material. Every bacteriologist knows that his culture tubes are much more likely to become contaminated if he places a rubber cup over the cotton-wool at the mouth of the tube than without this precaution, unless he takes especial pains to sterilize the cotton-wool and the mouth of the tube before applying the

rubber. It is almost impossible for the surgeon to keep his dressings for any length of time free from bacteria, and it is, therefore, advisable not to shut these bacteria into secretions and an atmosphere saturated with moisture, prevented, by an impermeable covering, from evaporation.

Some of the most important advances in antiseptic surgery have come from the efforts to dispense with the use ofdrainage tubes. The drainage tube question is a part of the much larger one: How shall the so-called dead spaces, that is, the cavities and recesses, in a wound be managed? The surgeon has at his disposal the choice between many various means for managing these spaces. He can drain the spaces, or stuff them with foreign material, or endeavor to obliterate them by pressure, or by buried sutures, or by inverting sutures, or by transplantation of flaps, or he can permit them to fill with blood, or he can let them alone. Doubtless no one of these methods is universally applicable; probably each one has its field of usefulness. The skill of the surgeon consists in large measure in the manner in which he exercises his judgment as to the management of the dead spaces in a wound, and I shall venture to say a few words on this important but still unsettled question only from a bacteriological point of view.

The following objections to the insertion of drainage tubes into wounds suggest themselves: *First.* They tend to remove bacteria which may get into a wound from the bactericidal influence of the tissues and animal juices. *Second.* Bacteria may travel by continuous growth or in other ways down the sides of a drainage tube and so penetrate into a wound which they otherwise would not enter. We have repeatedly been able to demonstrate this mode of entrance into a wound of the white staphylococcus found so commonly in the epidermis. The danger of leaving any part of a drainage tube exposed to the air is too evident to require mention. *Third.* The changing of dressing necessitated by the presence of drainage tubes increases in proportion to its frequency the chances of accidental infection. *Fourth.* The drainage tube keeps asunder tissues which might otherwise immediately unite. *Fifth.* Its presence as a foreign body is an irritant and increases exudation. *Sixth.* The withdrawal of tubes left any considerable time in wounds breaks up forming granulations and thus both prolongs the process of repair and opens the way for infection. Granulation tissue is an obstacle to the invasion of pathogenic bacteria from the surface, as has been proven by experiment. *Seventh.* After removal of the tube there is left a tract prone to suppurate and often slow in healing.

The advantage from the employment of drainage tubes is, of course, the removal of secretions, and this indication becomes an urgent one if the cavity with which the tube communicates becomes infected and suppurates. In a given case the surgeon must weigh the advantages and the disadvantages and act according to his judgment. The practice of many surgeons at the present time, of restricting within much narrower limits than formerly the use of drainage tubes and of discarding them for all wounds which offer a fair prospect of primary union, is a distinct advance in the technique of antiseptic surgery.

The practice of stuffing cavities with foreign substances, even those of an absorbable nature, is open to most of the objections already urged against drainage tubes.

Much can be accomplished by external pressure in bringing together the surfaces within a wound, but this procedure is of only limited application, for on the one hand only such spaces can be obliterated in this way as are favorably situated and have surfaces suitable for coaptation, and on the other hand there is difficulty in regulating the pressure so that it does not interfere with the circulation and with the vitality of the tissues.

The method elaborated especially by Neuber and by Küster, of obliterating spaces in a wound by means of deep coaptation sutures, has unquestionably given excellent results, but it is not free from serious objections. The conscientious execution of the method often is tedious and greatly prolongs the operation, and it may be doubted whether the object aimed at is not often missed. The most manifest objections however, are the presence in the wound of so many foreign bodies in the form of sutures as are often required, and especially the danger of strangulating and stretching unduly the tissues, and thus interfering with their anti-bacterial capacities. The thinner the sutures employed, the smaller is the danger of their presence as foreign bodies.

The idea that blood in a wound is a dangerous thing is a prevalent one, and such surgeons as Küster and von Bergmann in recent years have dwelt especially upon this danger. Blood is looked upon as a foreign substance more dangerous than most foreign substances because it is held to be especially prone to decomposition by bacteria. Nevertheless, John Hunter was fond of dwelling upon what he called the vitality of blood, and was acquainted with its so-called organization in wounds. Mr. John Chiene, about fifteen years ago, directed attention anew to the same views; but it was Schede who in 1886, in an article on the Healing of Wounds Under the Moist Blood Scab, brought prominently to the notice of surgeons the value of the blood clot in the healing of a certain class of wounds. The discoveries more recently made as to the power of fresh blood outside of the body to destroy many kinds of bacteria (although in only very limited degree the pyogenic cocci) or their poisonous products have shed additional light upon this subject. The credit of introducing as a method of general applicability the management of dead spaces by permitting them to fill with blood belongs to Halsted. Before him several surgeons, and Schede especially, had recommended the use of the blood clot for a limited class of wounds and for a limited purpose, but Halsted has substituted for all other methods previously employed in treating dead spaces not otherwise easily obliterated, that is, for drainage tubes, buried sutures, pressure, etc., the use of the blood clot as the method of widest applicability and as affording the best results. In a paper read before the recent Congress of American Physicians and Surgeons, I described the results of my experiments on animals, which supported the conclusions derived from clinical experience as to the value of the method of healing of wounds by allowing spaces to fill with blood. That the unintended presence of blood in a wound may be a source of danger by occasioning undue tension and in other ways, and is a very different thing from the purposeful application of the method of healing by so-called organization of blood coagula, hardly needs to be mentioned. Nor need I emphasize the fact that loss of blood, as such, is to be guarded against, for it is proven experimentally that general anaemia is a predisposing cause of infection with pyogenic bacteria.

The question suggests itself, what would happen under good antiseptic technique if the so-called dead spaces of a fresh operation wound were left to themselves, that is, were neither drained nor obliterated nor permitted to fill with blood? There is not sufficient experience to answer this question satisfactorily. This, however, is to be considered. Exudations composed of fluid and cells would quickly accumulate in most of these spaces, and these fluids and cells possess anti-bacterial properties as well as blood. Granulation tissue would spring up from the sides. I venture to predict that if the surgeon paid no particular attention to the filling or obliteration of many of the smaller spaces in fresh operation wounds, and if the antiseptic technique were good, the process of healing would be as satisfactory as by any of the other methods mentioned.

Let us now turn our attention to the progress which has been made in the employment of antiseptic agents for surgical purposes. Soon after the introduction of Lister's methods, the search began for new and better disinfectants than carbolic acid. This search brought to light a large number of agents, some good, but more of little or no value for the purpose intended, and in general, carbolic acid continued to possess the field until Koch, by his fundamental experiments with disinfectants, demonstrated the pre-eminent germicidal power of corrosive sublimate. This latter disinfectant has, to a large extent, although not entirely, taken the place formerly occupied by carbolic acid as the surgical disinfectant *par excellence*. In no department of antiseptic surgical technique has the value of bacteriological methods of experimentation been more evident than in establishing the germicidal powers of various real or supposed disinfectants; nevertheless, the importance of not rejecting sound clinical experience in this matter is shown by the fate of iodoform as an antiseptic agent. Iodoform would probably never have been recommended as an antiseptic on the basis of bacteriological experiments alone. Still, the benefits of its employment in wounds and surgical affections are undoubted, and a more careful study of the mode of action and the conditions required for the development of the antiseptic powers of iodoform has justified the use of this substance. A class of disinfectants obtained by fractional distillation at high temperatures of coal-tar oils has recently been introduced, and promises valuable service. These are the higher cresols, which pass over by distillation between 190° and 210°C. The difficulty has been to obtain these oils in a form soluble in water. Creolin is a fine emulsion of these cresols; and lysol, a solution of the same in water by a soap combination. Although, like most new disinfectants, creolin and lysol have not sustained the extravagant claims made for them by their early enthusiastic advocates, nevertheless they possess strongly disinfectant and other valuable properties and are a useful contribution to the list of surgical antiseptic agents.

But surgical disinfection has progressed not so much by the introduction of new chemical disinfectants as by a better understanding of the mode and conditions of their efficient action. It was once supposed that the skin, wounds, instruments, sponges, etc., could be completely disinfected, without any especial precautions, by being placed for a short time in the disinfectant solutions. Misleading inferences were drawn from the powerful germicidal action of chemical disinfectants when brought into contact with bacteria under the most favorable conditions, namely, with bacteria on silk threads or suspended in water. Not sufficient attention was paid to one of the most important results of Koch's investigations of disinfectants—that the presence of oil or fat prevents the parasiticide action of chemical disinfectants. From this it should have been clear that the presence of oily substances in the epidermis, and often, also, on instruments, sponges and other objects used by the surgeon, must frequently render his efforts at disinfection nugatory, unless by the use of alcohol or by thorough mechanical scrubbing with soap and water, he first removes the grease. Hence it might easily happen that those who scouted the use of chemical disinfectants but employed thorough mechanical cleansing of hands, instruments, etc., really attained a higher degree of antisepsis than those who trusted exclusively to chemical disinfection. Thorough mechanical cleansing and scrubbing with soap and water, although it accomplishes much, does not generally bring about complete disinfection and cannot, therefore, alone be trusted, but these measures are essential adjuvants of any method of surgical disinfection with chemical agents. It may be mentioned that the alkaline soaps possess some disinfectant power, often quite as much as especially prepared commercial disinfectant soaps.

The differences in germicidal power of corrosive sublimate under different conditions are much greater than those of carbolic acid and most other disinfectants. Aside from the presence of oily material, the great obstacle against the disinfectant action of corrosive sublimate in the animal tissues and fluids is its precipitation with albuminous substances. So great is the obstacle that it may be doubted whether it is possible to disinfect by means of corrosive sublimate wounds infected with bacteria, and whether irrigation with solutions of corrosive sublimate accomplishes much more in this way than that with sterile salt solution. We owe especially to Geppert the demonstration that former methods of testing the germicidal power of corrosive sublimate were subject to such grave errors that their results cannot be trusted. Geppert has shown that it is necessary to get rid of the sublimate, which can best be done by precipitation with sulphide of ammonium (or other alkaline sulphides), in order to determine whether bacteria subjected to its action have actually been killed or not. When this precaution is taken it is found that corrosive sublimate is a far less energetic disinfectant than has been generally supposed. For example, Koch believed from his experiments that corrosive sublimate in the strength of 1-1000 destroys anthrax spores in one minute, whereas Geppert has shown that the same strength of sublimate may not have killed all of the spores in watery suspension even at the end of 72 hours. In a recent article Geppert has shown that it is really very difficult to determine whether all of the spores are killed or not by sublimate, inasmuch as a definite concentration of the solution of sulphide used for precipitation is required to test this point and the failure to obtain cultures or to infect an animal is no proof that the spores have been killed, for a different concentration of the substance used to precipitate the sublimate or the employment for this purpose of some substance less injurious to the spores might demonstrate still greater resistance against sublimate. Dr. Abbott has gone over the question of disinfection of the staphylococcus pyogenes aureus with corrosive sublimate in my laboratory and his results in conformity with those of Geppert for other bacteriahave been made known to you. It may be that the powerful inhibitory and attenuating action of corrosive sublimate upon bacteria is all that is required for the purposes of the surgeon, but it should be understood that this is not equivalent to disinfection, which means the actual destruction of bacteria.

In view of the difficulties and uncertainties of securing under many conditions complete disinfection with chemical agents, especially with corrosive sublimate, it marks a great progress in surgical antisepsis that heat, in the form of dry heat, or live steam, or boiling, is now used so extensively by the surgeon for sterilization of instruments, ligatures, dressings, etc. That chemical disinfectants still have and are likely to continue to have important uses in surgical practice goes without saying.

As I have recently, before the Congress of American Physicians and Surgeons in Washington, presented some of the results of our experience with methods of disinfection of the skin, I shall utilize the present occasion to demonstrate to you a number of culture tubes which illustrate the results of experiments begun by Dr. Halsted, and carried farther by Drs. Ghriskey and Robb, in my laboratory.

A fact important to know in connection with experiments on cutaneous disinfection is that the mercury, probably in combination with albuminous material, remains for many days in the epidermis of hands which have been frequently washed in solutions of corrosive sublimate in the manner customary with surgeons, and this notwithstanding the ordinary daily ablutions with soap and water. Of this I will ask any surgeon present who uses frequently corrosive sublimate for disinfec-

tion of his hands to convince himself by placing his fingers in this solution of ammonium sulphide. A mere brownish discoloration of the surface of the skin after applying ammonium sulphide must not be taken as evidence of the presence of mercury, for this in varying degree can take place with those who have not been in contact with mercurial solutions, but it is the rapid deep brown or black discolortion, especially of the nails, which indicates the formation of sulphide of mercury. A pretty demonstration of the growth of the nails is furnished by the absence of the dark brown color in the part of the nail which has grown since the use of the sublimate solution. Not only may the mercury remain for a long time in the epidermis, but it is capable of preventing the growth of bacteria with which it originally came into contact when scrapings from the epidermis are placed in nutrient agar or gelatine. It does not, however, seem to exert any such inhibitory action upon bacteria which have become attached to the epidermis after the application of the sublimate. That epidermal bacteria which fail to grow in culture media inoculated with scrapings from the surface of the skin after washing with sublimate solutions are not necessarily dead, is proven by their development when the scrapings are taken from the same skin after precipitation of the mercury in the epidermis with sulphide of ammonium. For this result the experiments of Geppert had already prepared us, and it is the failure to precipitate the mercury with an alkaline sulphide which led Fürbringer to apparently better results than we have obtained in testing his method of disinfection of the hands with corrosive sublimate. It is also clear that erroneous conclusions may be derived from testing the germicidal power of any other disinfectant on the skin, if the hands of those who are in the habit of using sublimate solutions on them be selected as the object of disinfection, unless the precaution be taken first to get rid of the sublimate, which is best done by precipitating it as the sulphide of mercury.

If the hands have been washed, say the day before, in a solution of corrosive sublimate, then it may happen that most or all of the bacteria which have become attached to the skin since then can be removed by simple scrubbing with soap and water, or by some solution the disinfectant powers of which it is desired to test, and the cultures made from scrapings of the epidermis prove sterile. That, however, there are still living bacteria in the superficial layers of the epidermis, may be shown by making the cultures after washing the hands in solutions of ammonium sulphide. It is probable, from Geppert's recent work, that we should have obtained even more striking results if we had paid more attention in the experiments to the concentration of the solutions of sulphide of ammonium, but we were not familiar then with the importance of this point, and, as it is, the results were sufficiently striking.

I show you here a series of cultures which are intended to demonstrate the points mentioned. Scrapings from the epidermis or beneath the nails were made with a sterilized knife constructed for the purpose, and were transferred to liquefied agar, which was then rolled or poured into Petri's dishes.

In this first series of agar roll cultures there are three sets of tubes which have been inoculated with scrapings from the epidermis and beneath the nails of one of the assistants in the hospital who is in the habit of making daily use of sublimate solutions. The first set were inoculated with scrapings without any preliminary treatment of the hands; the second after thorough scrubbing with soap and warm water by means of a sterilized brush; and the third after washing the hands, subsequent to the scrubbing with soap and water, with a solution of sulphide of ammonium, which brought out a deep brown or black color of the epi-

dermis and nails. You will observe that all of the tubes of the first set contain a large number of colonies, that two of the tubes of the second set contain no colonies and two contain from three to ten colonies, and that the tubes of the third set contain from twenty to one hundred colonies.

In this second series of agar roll cultures, intended to show the results of Fürbringer's method, the experiment has been made with hands which have not previously been in sublimate solution. The first set of tubes were inoculated with scrapings from beneath the nails without preliminary treatment; the second after thorough scrubbing with soap and water; the third after the use of alcohol, and then washing in sublimate 1-500 for two minutes; and the fourth after washing the hands in sulphide of ammonium, which turned them dark in color. Each step was carried out strictly according to Fürbringer's directions, and double the amount of time which he recommends given to each step. The sublimate was freshly prepared in distilled water. The hands were well washed in sterilized water and then dried with a sterilized cloth before inoculating the third set of tubes. Each set was inoculated with the scrapings from beneath and around the nails and placed in the thermostat at 37°C. You will observe that the first set of tubes are crowded with colonies; that the second contain a smaller number, but still a good many colonies, from twenty to over a hundred; that the third set are sterile, save one colony in one of the tubes; and that the fourth set contain some colonies in each tube, varying from three to twenty-five. Fürbringer inferred from such results as those in the third set of tubes that the sublimate had actually killed all of the bacteria in the superficial layers of the epidermis and beneath the nails, whereas, if he had precipitated the mercury with ammonium sulphide as was done before inoculating the fourth set, he would have learned that this is not the case. It is fair to say that we have sometimes obtained sterile tubes by Fürbringer's method, even after precipitation with ammonium sulphide, and we do not intend to condemn the method as not a good one, but only as not the best, and as not accomplishing all that is claimed for it. As has already been said, it may be that it is sufficient to inhibit the growth of the bacteria in the way that is done by the sublimate, but it is not justifiable to infer that because the bacteria will not grow in our culture media they may not grow in the animal body. It is also to be considered that sublimate is capable of attenuating or destroying the pathogenic power of some bacteria. But even after giving due weight to these considerations, that method which actually kills the bacteria is to be preferred if it is applicable.

The third series of tubes has been inoculated with scrapings from beneath the nails after disinfecting the hands with lysol; and the fourth after disinfection with peroxide of hydrogen, the preliminary scrubbing with soap and water being as in the other experiments. You will observe that neither of these agents has accomplished complete disinfection, there being a few colonies in most of the tubes, the most in the tubes after using peroxide of hydrogen. The hands were disinfected with lysol in the manner recommended by Gerlach.

On the other hand, in this fifth series of tubes inoculated with scrapings from beneath the nails after disinfection with permanganate of potash and oxalic acid in the manner described in my paper before the Congress in Washington, you will observe that all of the tubes are sterile with the exception of one colony in one of the tubes. We, therefore, have adopted in the hospital this method of disinfection of the skin. Whether there may lurk some fallacy in the conclusions which we have drawn from our experiments with this method analogous to that in previous experiments with corrosive sublimate I cannot say, but if so, we have not been able to detect it.

Our experiments with methods of cutaneous disinfection, as well as our observations on the bacteria in wounds treated antiseptically, have led us to a study of the bacteria in the skin. The micro-organisms in the human epidermis have been studied by a number of investigators, as Bizzozero, Bordoni-Uffreduzzi, Unna, Maggiora, Mitmann and Preindlsberger, and a large number, over a hundred different species, have been more or less perfectly described. Our purpose has been not to make a complete study of the bacterial flora of the skin, although we do not regard such a study in the light of Fürbringer's characterization of it as a "zeitraubende, geistestödtende, wenig fördernde Beschäftigung," but rather to learn something about the frequency of occurrence of the most common pyogenic cocci, about the most common bacterial inhabitants of the epidermis and about the possibility of the presence of bacteria in layers of the epidermis not reached by existing methods of cutaneous disinfection.

In conformity with Fürbringer's statements as to the relation between the occupation of an individual and the bacteria present beneath the nails, we have found the staphylococcus pyogenes aureus only very exceptionally in the epidermis or in the subungual dirt of those who have had nothing to do with suppurating wounds, abscesses or other surgical cases, but on the other hand have found this organism repeatedly on the skin or beneath the nails of surgeons or their assistants. The bearing of these observations are sufficiently apparent to need no further emphasis.

We have found a white staphylococcus far more frequently than any other organism in the epidermis and beneath the nails after the superficial bacteria have been removed by scrubbing the hands with soap and water or by incomplete disinfection, as by washing with sublimate. Unna and others who have studied by culture methods and have paid attention to the relative frequency of the different kinds of bacteria on the skin have also noted the frequency of occurrence of a white coccus liquefying gelatine. Unna regards this most common coccus as the staphylococcus pyogenes albus. We have observed that this common epidermal staphylococcus liquefies gelatine and coagulates milk more slowly than the typical staphylococcus pyogenes albus, and that a centimeter and more of bouillon cultures can be injected without effect into the veins of rabbits. Whether this coccus is a distinct species or only a modified form of the staphylococcus pyogenes albus, we have not been able definitely to decide, but I have proposed for it, provisionally, the name staphylococcus epidermidis albus. Other white cocci also occur in the skin. We have met, several times, forms corresponding to the micrococcus cereus albus (Passet), the micrococcus candicans (Flügge) and the micrococcus albus liquefaciens (v. Besser). Von Besser has found in the normal air passages a white staphylococcus resembling the staphylococcus pyogenes albus save by the absence of pathogenic properties. In general, the classification of the white liquefying micrococci is difficult and unsatisfactory. There are differences in the rapidity of liquefaction of gelatine by our staphylococcus epidermidis albus and occasionally we have isolated forms which correspond in mode of growth to the staphylococcus pyogenes albus, but have not isolated any with the pathogenic powers of this coccus, so far as we have been able to test this point. We have also occasionally found in the epidermis a staphylococcus resembling closely, in the appearance of its colonies on agar and its scarcely visible growth on potato, the typhoid bacillus.

We regard as the most important outcome of our studies of the bacteria of the skin the demonstration of the presence of the staphylococcus epidermidis albus, less freqently of other bacteria, in layers of the skin deeper than can be reached by existing methods of disinfection of the skin. The significance of this fact is apparent when I tell you that this same coccus is the one which we have found

in a very large number of laparotomy wounds treated by the most careful antiseptic or aseptic methods and that it is the most frequent cause of stitch abscesses. We have found it so often in the deeper layers of the epidermis that we are inclined to consider it a regular inhabitant of the skin. It has only feeble pathogenic power ordinarily, but it is capable of causing suppuration. The injurious influence of a drainage tube in checking the repair of fresh healthy wounds is illustrated by the fact that it is chiefly in wounds containing drainage tubes that we have observed suppuration to result from the presence of this organism, and that often the suppuration is limited to the track occupied by the tube. This coccus is found not only in stitches around which suppuration has occurred, but also in those without any visible inflammatory reaction around them.

I show you here a number of cultures of this organism. These three cultures were made in the following way: the skin of a patient before an operation was thoroughly disinfected by the method already described, so that scrapings from the surface afforded no growth, then by means of a sterilized instrument; sterilized silk threads (tested by cultures), were drawn from one to five or six times through the disinfected skin and these silk threads were then dropped into liquefied agar, the tubes were agitated and then rolled on ice. You will observe that several white colonies (varying from two to ten), and coalescent colonies have developed, especially along the sides of the thread. The remaining five agar roll cultures have been inoculated with silk sutures removed from the skin, four to seven days after antiseptic laparotomies, pursuing in each case a perfectly aseptic course and without any evidence of inflammatory reaction around the stitches. Each of these tubes contains colonies of the white staphylococcus, varying from six to fifty in number.

We have found also other bacteria, and twice the staphylococcus pyogenes aureus, in skin stitches withdrawn after antiseptic operations, but the staphylococcus epidermidis albus is by far the most common. To judge from the number of colonies developed from sterilized threads drawn through the skin after complete disinfection of the surface it would seem as if the white staphylococcus were not particularly abundant in the epidermis. Further investigations, which must be microscopical, are necessary to determine the exact part of the epidermis or hair follicles or glandular appendages of the skin occupied by these bacteria, and here the methods recently described by Unna are likely to be of service.

I hardly need to say that these observations on the bacteria of the normal skin, and the depth to which they penetrate, indicate that the skin of the patient may be a source of wound infection and that the surgeon should take greater precautions than has hitherto been customary, to guard against this danger. Dr. Halsted, in view of our results on cutaneous disinfection, has discarded for the most part the use of cutaneous sutures, and is very well satisfied with the results obtained by bringing the edges of wounds together by subcutaneous sutures.

I have endeavored, gentlemen, to bring before you, although in a disconnected way, a few of the improvements in antiseptic surgery since Lister's pioneer work, as they present themselves to one looking at the subject from a bacteriological point of view. Surely progress has been great, but there is no reason to suppose that the ideal has yet been reached and that there is not room for further advance. Even in directions where it now seems to us that the goal is attained we must be guarded in our predictions, lest we make ourselves as ridiculous to future generations as to us seems the leading surgeon of his day, Boyer, when in the early part of this century he wrote "Surgery in our day has made the greatest progress and appears to have attained, or nearly so, the highest perfection of which it is capable."